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NEUTRON CROSS SECTIONS FOR TUNGSTEN ISOTOPES

by

G. D. Joanou
C. A. Stevens

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract SNPC-27

GENERAL ATOMIC

DIVISION OF

GENERAL DYNAMICS

JOHN JAY HOPKINS LABORATORY FOR PURE AND APPLIED SCIENCE

P.O. BOX 608, SAN DIEGO 12, CALIFORNIA

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TOPICAL REPORT

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November 13, 1964

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D. Bogart

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P.O. BOX 608, SAN DIEGO, CALIFORNIA 92112

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I. INTRODUCTION

A set of cross sections for the isotopes of tungsten, as well as for the natural element, has been obtained. The cross sections are based upon experimental data wherever possible, complemented with the results of nuclear model calculations. In some cases, where neither measurement nor a suitable calculation was available, it was necessary to make an "educated" guess. The results have been incorporated into the library tapes of the GAM-II⁽¹⁾ and GATHER-II⁽²⁾ computer programs.

II. DISCUSSION

2.1 POSSIBLE REACTIONS

The possible reactions between neutrons and each tungsten isotope, together with the thresholds, are shown in Table 1.⁽³⁾ Available measurements of the n, p and n, np cross sections⁽⁴⁾ indicate that these are so small that they can safely be ignored in reactor calculations. Since there are no existing measurements for most other reactions, these have been ignored. The only reactions which are believed to have significant cross sections are those for capture, inelastic scattering, elastic scattering, and the n, 2n reaction. These have been analyzed in this work.

2.2 CAPTURE CROSS SECTIONS

The resonance parameters of the individual tungsten isotopes have been evaluated, and a "best set" has been tabulated. In addition, strength functions for use above the resolved energy range were obtained. Values of the capture cross section at 2200 meters/sec and infinitely dilute resonance integrals, computed from the parameters, agree quite well with available measurements. The comparisons are presented below for each isotope.

2.2.1 Tungsten-182

The resonance parameters for this isotope are given in Table 2. They are based upon a recommended set obtained from the Brookhaven National Laboratory.⁽⁵⁾ The negative energy resonance, representing a bound level, was required to obtain a capture cross section of 20 barns at 2200 m/sec, in agreement with experiment.⁽⁶⁾ Instead of accepting

Table 1

POSSIBLE NEUTRON REACTIONS IN TUNGSTEN

Reaction	Thresholds (MeV)			
	<u>W¹⁸²</u>	<u>W¹⁸³</u>	<u>W¹⁸⁴</u>	<u>W¹⁸⁶</u>
n, p	0.96	0.29	1.90	2.94
n, np	7.06	7.19	7.75	8.44
n, d	4.82	4.95	5.51	6.19
n, nd	12.50	11.05	12.41	12.75
n, t	6.20	4.76	6.11	6.45
n, nt	13.02	12.45	12.23	12.32
n, He ³	5.53	5.77	6.61	-
n, nHe ³	12.90	11.76	13.23	14.51
n, He ⁴	0.0	0.0	0.0	0.0
n, nHe ⁴	0.0	0.0	0.0	0.0
n, 2n	8.03	6.23	7.46	7.31
n, 3n	15.02	14.27	13.69	13.09
n, γ	0.0	0.0	0.0	0.0
n, n'	0.1	0.0465	0.111	0.137

the recommended values for the radiation widths, the more theoretically plausible constant width of 57 mV, obtained from the average of the recommended values, was used. The capture cross section in the unresolved energy range was computed by the method of Garrison and Roos.⁽⁷⁾ From the resolved resonance parameters, the average level spacing was computed to be 60 eV. Because of a lack of data for W¹⁸², the s-wave strength function was taken to be equal to that computed from the resonance parameters of W¹⁸⁴, which is 3.1×10^{-4} eV^{-1/2}. The p-wave strength function was taken to be 0.5×10^{-4} eV^{-1/2}.⁽⁸⁾ The d-wave and f-wave strength functions were taken to be the same as for W¹⁸⁶. Finally, the infinitely dilute resonance integral to 0.414 eV was computed to be 591 barns.

2.2.2 Tungsten-183

Table 3 shows the resonance parameters used for the analysis. The value $\Gamma_\gamma = 81.6$ mV is a weighted average of the BNL recommended radiation widths, the weights having been chosen to be the reciprocals of the reported uncertainties in the measurements. Its use predicts a capture cross section of 9.51 barns at 2200 m/sec, in fair agreement with the experimental value of 11 ± 1 barns.⁽⁶⁾ The average level spacing and the s-wave strength function were computed to be 12.5 eV and 0.390×10^{-3} , respectively. The p, d, and f wave strength functions

were assumed to be the same for all isotopes, and were obtained as described for W¹⁸². The infinitely dilute resonance integral to 0.414 eV was computed to be 387.0 barns.

2.2.3 Tungsten-184

The resonance parameters for W¹⁸⁴ are shown in Table 4. It was necessary to postulate a bound level, as seen by the negative energy resonance, in order to agree with the experimental value of 2 barns at 2200 m/sec.⁽⁶⁾ The average level spacing and s-wave strength function were computed to be 140 eV and 3.1×10^{-4} , respectively.

The resonance integral to 0.414 eV was computed to be 13.5 barns, compared to an experimental value of 8.4 ± 2.0 barns⁽⁹⁾ and 7.5 ± 1.0 barns.⁽¹⁰⁾ This discrepancy has not been resolved. However, arbitrarily lowering the radiation width from its average value did not produce a significant change in the resonance integral. This insensitivity of the calculated resonance integral to the choice of radiation width leads one to question the measurements. In any case, the parameters were not "adjusted" to force agreement with the measured value.

2.2.4 Tungsten-186

The resonance parameters, which are based upon the BNL recommended set, are shown in Table 5. Their use predicts a capture cross section of 44.2 barns at 2200 m/sec, compared with the experimental value of 35 ± 3 barns reported in BNL-325. However, the activation cross section of W¹⁸⁶ in a thermal neutron spectrum has been measured to be 41.3 barns.⁽¹¹⁾ This corresponds to a value of 46.6 barns at 2200 m/sec, in agreement with the calculated value. The average level spacing was computed to be 100 eV, and the s-wave strength function was chosen to be equal to that of W¹⁸⁴. The p-wave strength function was taken from reference (8), and the d- and f-wave strength functions were obtained by fitting the data for the capture cross section in reference (6). In this manner, the d-wave and f-wave strength functions were computed to be 2×10^{-4} and $0.2 \times 10^{-4} \text{ eV}^{-1/2}$, respectively. The infinitely dilute resonance integral was computed to be 551 barns. Measured values are 490 ± 80 barns,⁽¹⁰⁾ and 560 ± 50 barns.⁽¹²⁾

2.2.5 Natural Tungsten

By weighting the results for the individual isotopes by their natural abundances, the cross sections for natural tungsten can be computed. The use of the strength functions used is then further justified in that the predicted capture cross sections agree very well with experimental values over a large energy range.⁽¹³⁾ The resonance integral is computed to be

372 barns, in agreement with the measured values of 360 ± 70 barns,⁽⁹⁾ 367 ± 33 barns,⁽¹⁴⁾ and 370 ± 60 barns.⁽¹⁰⁾ Furthermore, the computed value of the 2200 m/sec capture cross section is 19.9 barns, in fair agreement with measured values of 19.2 ± 1 barns⁽⁶⁾ and 18.8 ± 0.8 barns.⁽¹⁵⁾

Table 2
RESONANCE PARAMETERS FOR TUNGSTEN-182

E_o (eV)	Γ_n (mV)	Γ_γ (mV)	Γ_n^o	g
-44.6	269.0	57		1
4.15	1.47	57	0.72	1
21.2	39	57	8.4	1
114.4	269	57	25.2	1
213.0	7	57	.5	1
249.3	1030	57	65.0	1

Table 3
RESONANCE PARAMETERS FOR TUNGSTEN-183

E_o (eV)	Γ_n (mV)	Γ_γ (mV)	Γ_n^o	g
7.65	1.80	81.6	.65	.75
27.13	42.0	81.6	8.1	.75
40.6	1.7	81.6	.27	.75
46.08	154.0	81.6	22.7	.75
47.8	115.0	81.6	16.6	.25
66.0	1.6	81.6	.20	.75
100.8	100.0	81.6	10.0	.75
137.7	4.5	81.6	.38	.5
144.5	100.0	81.6	8.3	.25
155.0	400.0	81.6	32.0	.25
157.1	67.0	81.6	5.3	.75
174.1	70.0	81.6	5.3	.75
192.4	35.0	81.6	2.5	.75

Table 4
RESONANCE PARAMETERS FOR TUNGSTEN-184

E_o (eV)	Γ_n (mV)	Γ_Y (mV)	$\frac{\Gamma}{n}^o$	g
-155.4	1620			1
102.0	2.7	57	.27	1
184.5	1120	57	82	1
312	85	57	4.8	1
425	70	57	3.4	1
685	800	57	31	1
803	1950	57	69	1
963	1500	57	48	1
1090	3600	57	109	1
1137	300	57	9	1
1266	1100	57	31	1
1400	4400	57	118	1
1520	2100	57	54	1
1650	500	57	12	1
1790	1400	57	33	1
2037	2200	57	50	1
2093	5300	57	120	1

Table 5
RESONANCE PARAMETERS FOR TUNGSTEN-186

E_o (eV)	Γ_n (mV)	Γ_Y (mV)	$\frac{\Gamma}{n}^o$	g
18.83	317	52	72.7	1
171.5	40	52	3.1	1

2.3 INELASTIC SCATTERING

Optical model calculations, together with Hauser-Feshbach⁽¹⁶⁾ calculations, were used to compute total inelastic cross sections, elastic cross sections, and partial inelastic cross sections for each tungsten isotope in the energy range in which the level scheme is known. The potential chosen for the optical model calculations had a real part of the Woods-Saxon⁽¹⁷⁾ form and an imaginary part of the Gaussian form.⁽¹⁸⁾ The parameters chosen for the potential were the "set A" which was used by S. O. Moore and E. H. Auerbach in their calculations for W¹⁸⁴.⁽¹⁹⁾ The energy level schemes for the tungsten isotopes which were used for the calculations are: For W¹⁸², 0(0+), 0.100(2+), 0.329(4+), 0.680(6+),

1.222(2+), 1.255(2-), 1.290(2-), 1.332(3+), 1.374(3-); for W¹⁸³, 0(1/2-), 0.0465 (3/2-), 0.0991(5/2-), 0.207(7/2-), 0.2088(3/2-), 0.29171(5/2-), 0.30894(9/2-), 0.39420(9/2+), 0.41208(7/2-), 0.45308(7/2-); for W¹⁸⁴, 0(0+), 0.111(2+), 0.364(4+), 0.690(0+), 0.904(2+), 1.001(2+), 1.006(3+), 1.15(2+); for W¹⁸⁶, 0(0+), 0.122(2+), 0.40(4+), 0.730(2+), 0.85(3+), 1.04(4+). These were taken from the extended compilation of K.Way, et al.⁽²⁰⁾ The parity and spin of the first excited state of W¹⁸⁶ apparently is not known. It was taken to be 2+ because of the similarity of the level structure to the other even-even tungsten isotopes.

Above the energy range for which the level schemes are known, the nonelastic cross section was assumed to be the same for each isotope. The cross section was obtained from BNL-325. Inelastic cross sections for each isotope were then computed by subtracting the capture and n, 2n cross sections from the nonelastic cross section. The emission spectrum for these neutrons was computed from the nuclear temperatures which were measured at Duke University.⁽²¹⁾ The same temperatures were used for all isotopes.

2.4 n, 2n CROSS SECTION

No measurements exist for the n, 2n cross section of tungsten. By examining the thresholds in Table 1, it was seen that the thresholds were approximately the same for all the isotopes. It was therefore assumed that the n, 2n cross section had the same magnitude for all the isotopes, except in the immediate vicinity of the threshold energy, and its magnitude was chosen so that the natural element would have the same cross section as that deduced by Howerton.⁽²²⁾

2.5 TOTAL CROSS SECTION

The total cross section was obtained directly from reference 6. The optical model calculations, mentioned previously, were used to fill the gaps.

2.6 ELASTIC SCATTERING

The elastic scattering cross section was obtained by subtracting the nonelastic cross section from the total cross section. The nonelastic cross section is, of course, the sum of the capture, inelastic, and n, 2n cross sections.

Legendre coefficients for the angular distribution of elastically scattered neutrons in the center of mass system were obtained from a least squares analysis of the data in BNL-400⁽²³⁾ and Howerton's⁽²⁴⁾ compilation. The Legendre coefficients were defined so that

$$\sigma(E, \mu) = \sum \frac{2\ell + 1}{2} f_\ell(E) P_\ell(\mu) . \quad (1)$$

These were assumed to be the same for all the tungsten isotopes.

2.7 LOW ENERGY CROSS SECTIONS

Low energy capture cross sections were computed at the 101 energy points which are used in the GATHER-II program.⁽²⁾ Contributions from single level Breit-Wigner resonances were summed at each of the 101 energy points. The resonance parameters which were used are those listed in Tables 2 to 5. As was mentioned previously, the capture cross section of natural tungsten at 2200 m/sec, based upon the values for the individual isotopes, is 19.9 barns. Although this value agrees with experiment, the total cross section of 28.1 barns at the same energy is higher than the observed approximate value of 24 barns.^(6, 7) This discrepancy might be resolved if the quoted value for the potential scattering cross section (5 ± 1 barns)⁽⁶⁾ proves to be too high and/or if the neutron width of the 18.8 eV resonance of W¹⁸⁶ which was used is too high.

2.8 CROSS SECTION TABULATIONS

The cross sections discussed above, for each isotope, are shown in Tables 6 to 17.

Table 6

CROSS SECTIONS FOR TUNGSTEN-182

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)	$\sigma_{n,2n}$ (barns)
15.0	5.60	2.47	3.13	0.0125	0.56	1.90
14.5	5.55	2.48	3.07	0.0127	0.52	1.95
14.0	5.40	2.48	2.92	0.0130	0.42	2.05
13.5	5.30	2.49	2.81	0.0131	0.38	2.10
13.0	5.25	2.49	2.76	0.0135	0.33	2.15
12.5	5.25	2.49	2.76	0.014	0.30	2.18
12.0	5.15	2.50	2.65	0.0145	0.34	2.15
11.5	5.10	2.50	2.60	0.015	0.41	2.07
11.0	5.10	2.50	2.60	0.0155	0.56	1.92
10.5	5.05	2.50	2.55	0.0158	0.83	1.65
10.0	5.05	2.50	2.55	0.0161	1.33	1.15
9.8	5.05	2.50	2.55	0.0165	1.56	0.92
9.6	5.05	2.51	2.54	0.017	1.89	0.60
9.4	5.05	2.51	2.54	0.0173	2.04	0.45
9.2	5.05	2.52	2.53	0.0175	2.15	0.35
9.0	5.05	2.52	2.53	0.0178	2.20	0.30
8.8	5.05	2.53	2.52	0.018	2.31	0.20
8.6	5.06	2.53	2.53	0.0181	2.36	0.15
8.4	5.07	2.54	2.53	0.0182	2.41	0.11
8.2	5.09	2.54	2.55	0.0185	2.43	0.09
8.0	5.10	2.55	2.55	0.0190	2.53	0.0
7.8	5.12	2.55	2.57	0.0195	2.53	
7.6	5.14	2.55	2.59	0.0200	2.53	
7.4	5.16	2.55	2.61	0.0201	2.53	
7.2	5.18	2.55	2.63	0.0205	2.53	
7.0	5.20	2.55	2.65	0.021	2.53	
6.8	5.20	2.55	2.65	0.0215	2.53	
6.6	5.25	2.56	2.69	0.022	2.54	
6.4	5.30	2.56	2.74	0.0221	2.54	
6.2	5.40	2.56	2.84	0.0229	2.54	
6.0	5.45	2.56	2.89	0.0231	2.54	
5.8	5.50	2.57	2.93	0.024	2.55	
5.6	5.55	2.58	2.97	0.0245	2.56	

Table 6 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-182

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
5.4	5.70	2.59	3.11	0.0249	2.57
5.2	5.75	2.60	3.15	0.0255	2.57
5.0	5.75	2.60	3.15	0.0265	2.57
4.9	5.8	2.60	3.20	0.0270	2.57
4.8	5.85	2.60	3.25	0.0275	2.57
4.7	5.90	2.60	3.30	0.0280	2.57
4.6	5.95	2.60	3.35	0.0285	2.57
4.5	5.97	2.60	3.37	0.0292	2.57
4.4	6.0	2.60	3.40	0.0295	2.57
4.3	6.05	2.60	3.45	0.0300	2.57
4.2	6.1	2.60	3.50	0.0310	2.57
4.1	6.15	2.60	3.55	0.0315	2.57
4.0	6.20	2.60	3.60	0.0325	2.57
3.9	6.26	2.61	3.65	0.0330	2.58
3.8	6.32	2.61	3.71	0.0335	2.58
3.7	6.38	2.61	3.77	0.0340	2.58
3.6	6.44	2.61	3.83	0.0350	2.58
3.5	6.5	2.62	3.88	0.0355	2.58
3.4	6.56	2.62	3.94	0.0360	2.58
3.3	6.62	2.62	4.00	0.0370	2.58
3.2	6.68	2.62	4.06	0.0380	2.58
3.1	6.74	2.62	4.12	0.0390	2.58
3.0	6.8	2.62	4.18	0.0395	2.58
2.9	6.9	2.63	4.27	0.0405	2.59
2.8	6.95	2.63	4.32	0.0420	2.59
2.7	7.0	2.64	4.36	0.0430	2.60
2.6	7.0	2.64	4.36	0.0440	2.60
2.5	7.0	2.64	4.36	0.0450	2.59
2.4	7.0	2.64	4.36	0.0465	2.59
2.3	7.0	2.60	4.40	0.0480	2.55
2.2	7.0	2.55	4.45	0.0495	2.50
2.1	7.0	2.50	4.50	0.0510	2.45
2.0	7.0	2.46	4.54	0.0520	2.41
1.9	7.0	2.42	4.58	0.0540	2.37

Table 6 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-182

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
1.8	7.0	2.37	4.63	0.0560	2.31
1.7	7.0	2.30	4.70	0.0580	2.24
1.6	7.0	2.25	4.75	0.0600	2.19
1.5	7.0	2.15	4.85	0.0620	2.09
1.4	6.95	2.08	4.87	0.0650	2.01
1.3	6.95	2.02	4.93	0.0680	1.95
1.2	6.95	1.94	5.01	0.0720	1.87
1.1	6.95	1.94	5.01	0.0760	1.86
1.0	6.95	1.93	5.02	0.0800	1.85
0.95	6.95	1.9	5.05	0.0820	1.82
0.90	6.95	1.90	5.05	0.0840	1.82
0.85	6.95	1.88	5.07	0.0860	1.79
0.80	6.95	1.85	5.10	0.0890	1.76
0.75	6.97	1.82	5.15	0.0920	1.73
0.70	7.01	1.81	5.20	0.0950	1.71
0.65	7.05	1.77	5.28	0.0980	1.67
0.60	7.06	1.72	5.34	0.1020	1.62
0.55	7.20	1.67	5.53	0.1080	1.56
0.50	7.25	1.60	5.65	0.1120	1.49
0.45	7.40	1.50	5.90	0.1180	1.38
0.40	7.41	1.43	5.98	0.1220	1.31
0.35	7.65	1.32	6.33	0.1300	1.19
0.30	7.77	1.18	6.59	0.1410	1.04
0.25	8.10	0.97	7.13	0.1520	0.82
0.20	8.50	0.87	7.63	0.1720	0.70
0.15	8.85	0.54	8.31	0.1890	0.35
0.10	9.99	0.20	9.78	0.2000	0.0
0.095	10.0	0.20	9.80	0.2020	
0.080	10.1	0.21	9.89	0.2100	
0.070	10.2	0.22	9.98	0.2180	
0.060	10.4	0.23	10.2	0.2250	
0.050	10.5	0.24	10.3	0.2400	
0.040	10.6	0.26	10.3	0.2600	
0.03	10.8	0.29	10.5	0.2880	
0.02	11.2	0.34	10.9	0.3350	
0.015	11.5	0.39	11.1	0.3850	
0.01	11.85	0.48	11.4	0.4750	

Table 7

PARTIAL INELASTIC CROSS SECTIONS FOR TUNGSTEN-182

<u>E</u> <u>(MeV)</u>	<u>0.10</u>	<u>0.329</u>	<u>0.68</u>	<u>1.222</u>	<u>1.255</u>	<u>1.29</u>	<u>1.332</u>	<u>1.374</u>
1.4	1.06	0.35	0.013	0.22	0.138	0.112	0.071	0.036
1.3	1.26	0.39	0.01	0.168	0.092	0.0	0.0	0.0
1.2	1.46	0.40	0.006	0.0	0.0			
1.1	1.50	0.36	0.004					
1.0	1.53	0.32	0.002					
0.95	1.54	0.30	0.001					
0.90	1.55	0.27	0.0					
0.85	1.55	0.24						
0.80	1.56	0.20						
0.75	1.56	0.17						
0.70	1.56	0.15						
0.65	1.55	0.12						
0.60	1.54	0.09						
0.55	1.50	0.06						
0.50	1.45	0.04						
0.45	1.36	0.02						
0.40	1.30	0.004						
0.35	1.19	0.0						
0.30	1.04							
0.25	0.72							
0.20	0.70							
0.15	0.35							
0.10	0.0							

Table 8

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-182

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
1	0.001	99.61	5.79	105.4
2	0.002	70.45	5.76	76.2
3	0.004	49.84	5.75	55.6
4	0.005	44.59	5.75	50.3
5	0.007	37.71	5.75	43.5
6	0.008	35.28	5.74	41.0
7	0.01	31.57	5.74	37.3
8	0.015	25.81	5.74	31.5
9	0.02	22.38	5.74	28.1
10	0.0253	19.93	5.74	25.7
11	0.03	18.32	5.74	24.1
12	0.04	15.91	5.74	21.6
13	0.05	14.26	5.74	20.0
14	0.06	13.05	5.74	18.8
15	0.065	12.56	5.74	18.3
16	0.07	12.12	5.74	17.9
17	0.075	11.72	5.74	17.5
18	0.08	11.36	5.74	17.10
19	0.085	11.04	5.74	16.78
20	0.09	10.74	5.74	16.48
21	0.095	10.47	5.74	16.21
22	0.10	10.22	5.74	15.96
23	0.12	9.38	5.74	15.11
24	0.14	8.73	5.74	14.47
25	0.16	8.21	5.74	13.95
26	0.18	7.78	5.74	13.52
27	0.20	7.42	5.74	13.16
28	0.22	7.12	5.74	12.85
29	0.23	6.98	5.74	12.72
30	0.24	6.85	5.74	12.59
31	0.25	6.73	5.74	12.47
32	0.26	6.62	5.74	12.36
33	0.27	6.51	5.74	12.25
34	0.28	6.42	5.74	12.15
35	0.29	6.32	5.74	12.06
36	0.30	6.23	5.74	11.97
37	0.31	6.15	5.74	11.89
38	0.32	6.07	5.74	11.81
39	0.33	5.99	5.74	11.73

Table 8 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-182

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
40	0.34	5.92	5.74	11.66
41	0.35	5.86	5.74	11.59
42	0.36	5.79	5.74	11.53
43	0.38	5.67	5.74	11.41
44	0.414	5.49	5.74	11.23
45	0.42	5.46	5.74	11.20
46	0.43	5.41	5.74	11.15
47	0.45	5.32	5.74	11.06
48	0.46	5.28	5.74	11.02
49	0.47	5.24	5.74	10.97
50	0.475	5.22	5.74	10.96
51	0.48	5.20	5.74	10.94
52	0.49	5.17	5.74	10.90
53	0.50	5.13	5.74	10.87
54	0.532	5.02	5.74	10.76
55	0.55	4.97	5.74	10.71
56	0.575	4.90	5.74	10.64
57	0.59	4.86	5.74	10.60
58	0.60	4.84	5.74	10.58
59	0.625	4.78	5.74	10.52
60	0.65	4.73	5.74	10.47
61	0.683	4.67	5.74	10.40
62	0.70	4.64	5.74	10.37
63	0.75	4.56	5.74	10.30
64	0.80	4.50	5.74	10.23
65	0.85	4.44	5.74	10.18
66	0.876	4.42	5.74	10.16
67	0.890	4.41	5.74	10.15
68	0.91	4.39	5.74	10.13
69	0.93	4.38	5.74	10.12
70	0.95	4.37	5.74	10.11
71	0.97	4.36	5.74	10.10
72	0.98	4.35	5.74	10.10
73	0.99	4.35	5.74	10.09
74	1.00	4.35	5.74	10.09
75	1.025	4.34	5.74	10.08

Table 8 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-182

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
76	1.05	4.33	5.74	10.07
77	1.06	4.33	5.74	10.07
78	1.07	4.33	5.74	10.07
79	1.08	4.32	5.74	10.07
80	1.09	4.32	5.74	10.07
81	1.11	4.32	5.74	10.06
82	1.125	4.32	5.74	10.06
83	1.13	4.32	5.74	10.06
84	1.15	4.32	5.74	10.06
85	1.20	4.33	5.74	10.07
86	1.25	4.34	5.75	10.08
87	1.30	4.35	5.75	10.10
88	1.35	4.38	5.75	10.13
89	1.44	4.44	5.75	10.19
90	1.50	4.49	5.75	10.24
91	1.60	4.59	5.75	10.35
92	1.70	4.73	5.76	10.48
93	1.78	4.86	5.76	10.62
94	1.86	5.00	5.76	10.77
95	1.90	5.09	5.77	10.85
96	2.00	5.32	5.77	11.10
97	2.10	5.60	5.78	11.38
98	2.20	5.94	5.79	11.72
99	2.29	6.29	5.80	12.08
100	2.33	6.46	5.80	12.26
101	2.38	6.70	5.81	12.51

Table 9
CROSS SECTIONS FOR TUNGSTEN-183

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{e1} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)	$\sigma_{n,2n}$ (barns)
15.0	5.60	2.46	3.13	0.032	0.53	1.90
14.5	5.55	2.47	3.07	0.0325	0.49	1.95
14.0	5.40	2.48	2.92	0.033	0.39	2.05
13.5	5.30	2.49	2.81	0.034	0.35	2.10
13.0	5.25	2.49	2.76	0.035	0.30	2.15
12.5	5.25	2.49	2.76	0.037	0.27	2.18
12.0	5.15	2.49	2.65	0.038	0.30	2.15
11.5	5.10	2.49	2.60	0.039	0.30	2.15
11.0	5.10	2.49	2.60	0.040	0.40	2.05
10.5	5.05	2.49	2.55	0.042	0.55	1.90
10.0	5.05	2.49	2.55	0.043	0.71	1.74
9.8	5.05	2.49	2.55	0.044	0.85	1.60
9.6	5.05	2.51	2.54	0.045	0.96	1.50
9.4	5.05	2.50	2.54	0.046	1.00	1.45
9.2	5.05	2.51	2.53	0.047	1.16	1.30
9.0	5.05	2.51	2.53	0.048	1.26	1.20
8.8	5.06	2.53	2.53	0.048	1.58	0.90
8.6	5.06	2.53	2.53	0.049	1.88	0.60
8.4	5.07	2.54	2.53	0.050	1.99	0.50
8.2	5.09	2.54	2.55	0.051	2.09	0.40
8.0	5.10	2.54	2.55	0.052	2.19	0.30
7.8	5.12	2.54	2.57	0.053	2.29	0.20
7.6	5.14	2.55	2.59	0.054	2.33	0.17
7.4	5.16	2.56	2.61	0.055	2.34	0.16
7.2	5.18	2.55	2.63	0.057	2.36	0.135
7.0	5.20	2.56	2.65	0.058	2.37	0.125
6.8	5.20	2.56	2.65	0.060	2.38	0.115
6.6	5.25	2.56	2.69	0.061	2.39	0.105
6.4	5.30	2.55	2.74	0.063	2.39	0.10
6.2	5.40	2.56	2.84	0.065	2.49	0.0
6.0	5.45	2.56	2.89	0.066	2.49	
5.8	5.50	2.57	2.93	0.068	2.50	
5.6	5.55	2.58	2.97	0.070	2.51	
5.4	5.70	2.58	3.11	0.072	2.51	

Table 9 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-183

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n, \gamma}$ (barns)	σ_{in} (barns)
5.2	5.75	2.59	3.16	0.074	2.52
5.0	5.75	2.60	3.15	0.076	2.52
4.9	5.8	2.60	3.20	0.078	2.52
4.8	5.85	2.60	3.25	0.079	2.52
4.7	5.90	2.60	3.30	0.080	2.52
4.6	5.95	2.60	3.35	0.082	2.52
4.5	5.97	2.60	3.37	0.084	2.52
4.4	6.00	2.60	3.40	0.086	2.51
4.3	6.05	2.60	3.45	0.087	2.51
4.2	6.10	2.60	3.50	0.088	2.51
4.1	6.15	2.60	3.55	0.090	2.51
4.0	6.20	2.60	3.60	0.093	2.51
3.9	6.26	2.61	3.65	0.095	2.51
3.8	6.32	2.61	3.71	0.096	2.51
3.7	6.38	2.61	3.77	0.098	2.51
3.6	6.44	2.61	3.83	0.100	2.51
3.5	6.50	2.61	3.89	0.102	2.51
3.4	6.56	2.62	3.94	0.105	2.51
3.3	6.62	2.62	4.00	0.107	2.51
3.2	6.68	2.62	4.06	0.110	2.51
3.1	6.74	2.62	4.12	0.112	2.51
3.0	6.80	2.62	4.18	0.115	2.51
2.9	6.90	2.63	4.27	0.118	2.51
2.8	6.95	2.63	4.32	0.120	2.51
2.7	7.00	2.63	4.37	0.122	2.51
2.6	7.00	2.64	4.36	0.125	2.51
2.5	7.00	2.64	4.36	0.129	2.51
2.4	7.00	2.64	4.36	0.131	2.51
2.3	7.00	2.65	4.35	0.135	2.51
2.2	7.00	2.63	4.37	0.138	2.49
2.1	7.00	2.62	4.38	0.140	2.48
2.0	7.00	2.62	4.38	0.145	2.47
1.9	7.00	2.60	4.40	0.148	2.45
1.8	7.00	2.56	4.44	0.152	2.41
1.7	7.00	2.56	4.44	0.158	2.40

Table 9 (Cont.)
CROSS SECTIONS FOR TUNGSTEN-183

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n, \gamma}$ (barns)	σ_{in} (barns)
1. 6	7. 00	2. 54	4. 46	0. 162	2. 38
1. 5	7. 00	2. 52	4. 48	0. 170	2. 35
1. 4	6. 95	2. 50	4. 45	0. 175	2. 32
1. 3	6. 95	2. 45	4. 50	0. 182	2. 27
1. 2	6. 95	2. 42	4. 53	0. 190	2. 23
1. 1	6. 95	2. 32	4. 63	0. 200	2. 12
1. 0	6. 95	2. 27	4. 68	0. 210	2. 06
0. 95	6. 95	2. 27	4. 68	0. 215	2. 05
0. 90	6. 95	2. 25	4. 70	0. 220	2. 03
0. 85	6. 95	2. 25	4. 70	0. 228	2. 02
0. 80	6. 95	2. 23	4. 72	0. 235	1. 99
0. 75	6. 97	2. 22	4. 75	0. 241	1. 98
0. 70	7. 00	2. 21	4. 79	0. 250	1. 96
0. 65	7. 05	2. 20	4. 85	0. 260	1. 94
0. 60	7. 10	2. 20	4. 90	0. 270	1. 93
0. 55	7. 15	2. 18	4. 97	0. 281	1. 90
0. 50	7. 19	2. 13	5. 06	0. 295	1. 83
0. 45	7. 30	2. 07	5. 23	0. 310	1. 76
0. 40	7. 41	2. 03	5. 38	0. 320	1. 71
0. 35	7. 60	1. 99	5. 61	0. 338	1. 65
0. 30	7. 77	1. 92	5. 85	0. 358	1. 56
0. 25	8. 15	1. 75	6. 40	0. 371	1. 38
0. 20	8. 50	1. 68	6. 82	0. 390	1. 29
0. 15	8. 85	1. 67	7. 18	0. 410	1. 26
0. 10	10. 19	1. 64	8. 55	0. 440	1. 20
0. 095	10. 2	1. 62	8. 58	0. 450	1. 17
0. 080	10. 3	1. 55	8. 75	0. 460	1. 09
0. 070	10. 4	1. 40	9. 00	0. 481	0. 92
0. 060	10. 5	1. 12	9. 38	0. 500	0. 62
0. 050	10. 5	0. 72	9. 78	0. 525	0. 19
0. 040	10. 6	0. 57	10. 03	0. 574	0. 0
0. 03	10. 8	0. 66	10. 14	0. 660	
0. 02	11. 2	0. 84	10. 36	0. 840	
0. 015	11. 5	0. 98	10. 52	0. 980	
0. 01	11. 85	1. 20	10. 65	1. 20	

Table 10

PARTIAL INELASTIC CROSS SECTIONS FOR TUNGSTEN-183

Table 11

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-183

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
1	0.001	47.65	5.21	52.87
2	0.002	33.70	5.20	38.91
3	0.004	23.83	5.20	29.04
4	0.005	21.32	5.20	26.52
5	0.007	18.02	5.20	23.23
6	0.008	16.86	5.20	22.06
7	0.010	15.08	5.20	20.29
8	0.015	12.32	5.20	17.53
9	0.020	10.68	5.20	15.88
10	0.025	9.50	5.20	14.70
11	0.030	8.73	5.20	13.93
12	0.040	7.57	5.20	12.77
13	0.050	6.78	5.20	11.98
14	0.060	6.19	5.20	11.40
15	0.065	5.95	5.20	11.16
16	0.070	5.74	5.20	10.94
17	0.075	5.55	5.20	10.75
18	0.080	5.38	5.20	10.58
19	0.085	5.22	5.20	10.42
20	0.090	5.07	5.20	10.28
21	0.095	4.94	5.20	10.14
22	0.100	4.82	5.20	10.02
23	0.120	4.41	5.20	9.61
24	0.140	4.09	5.20	9.30
25	0.160	3.84	5.20	9.04
26	0.180	3.63	5.20	8.83
27	0.200	3.45	5.20	8.65
28	0.220	3.30	5.20	8.50
29	0.230	3.23	5.20	8.43
30	0.240	3.16	5.20	8.37
31	0.250	3.10	5.20	8.31
32	0.260	3.05	5.20	8.25
33	0.270	2.99	5.20	8.20
34	0.280	2.94	5.20	8.15
35	0.290	2.89	5.20	8.10
36	0.300	2.85	5.20	8.05
37	0.310	2.81	5.20	8.01
38	0.320	2.77	5.20	7.98
39	0.330	2.73	5.20	7.93

Table 11 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-183

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
40	0.340	2.69	5.20	7.89
41	0.350	2.65	5.20	7.86
42	0.360	2.62	5.20	7.83
43	0.380	2.56	5.20	7.76
44	0.414	2.46	5.20	7.67
45	0.420	2.44	5.20	7.65
46	0.430	2.42	5.20	7.62
47	0.450	2.37	5.20	7.57
48	0.460	2.35	5.21	7.55
49	0.470	2.33	5.21	7.53
50	0.475	2.31	5.21	7.52
51	0.480	2.30	5.21	7.51
52	0.490	2.28	5.21	7.49
53	0.500	2.26	5.21	7.47
54	0.532	2.20	5.21	7.41
55	0.550	2.17	5.21	7.38
56	0.575	2.13	5.21	7.34
57	0.590	2.11	5.21	7.31
58	0.600	2.09	5.21	7.30
59	0.625	2.06	5.21	7.26
60	0.650	2.02	5.21	7.23
61	0.683	1.98	5.21	7.19
62	0.700	1.96	5.21	7.17
63	0.750	1.91	5.21	7.12
64	0.800	1.86	5.21	7.07
65	0.850	1.82	5.21	7.03
66	0.876	1.80	5.21	7.01
67	0.890	1.79	5.21	7.00
68	0.910	1.77	5.21	6.98
69	0.930	1.76	5.21	6.97
70	0.950	1.74	5.21	6.95
71	0.970	1.73	5.21	6.94
72	0.980	1.72	5.21	6.93
73	0.099	1.72	5.21	6.93
74	1.000	1.71	5.21	6.92

Table 11 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-183

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
75	1.025	1.70	5.21	6.91
76	1.050	1.68	5.21	6.89
77	1.060	1.68	5.21	6.89
78	1.070	1.67	5.21	6.88
79	1.080	1.66	5.21	6.88
80	1.090	1.66	5.21	6.87
81	1.110	1.65	5.21	6.86
82	1.125	1.64	5.21	6.86
83	1.130	1.64	5.21	6.85
84	1.150	1.63	5.21	6.84
85	1.200	1.61	5.21	6.82
86	1.250	1.59	5.21	6.80
87	1.300	1.57	5.21	6.78
88	1.350	1.55	5.22	6.77
89	1.440	1.52	5.22	6.74
90	1.500	1.50	5.22	6.72
91	1.600	1.48	5.22	6.70
92	1.700	1.46	5.22	6.68
93	1.780	1.45	5.22	6.67
94	1.860	1.43	5.22	6.65
95	1.900	1.43	5.22	6.65
96	2.000	1.42	5.22	6.64
97	2.100	1.41	5.23	6.63
98	2.200	1.40	5.23	6.63
99	2.290	1.40	5.23	6.63
100	2.330	1.40	5.23	6.63
101	2.380	1.40	5.23	6.63

Table 12

CROSS SECTIONS FOR TUNGSTEN-184

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)	$\sigma_{n, 2n}$ (barns)
15.0	5.60	2.47	3.13	0.0059	0.56	1.90
14.5	5.55	2.48	3.07	0.006	0.52	1.95
14.0	5.40	2.48	2.92	0.0062	0.42	2.05
13.5	5.30	2.49	2.81	0.0064	0.38	2.10
13.0	5.25	2.49	2.76	0.0066	0.33	2.15
12.5	5.25	2.51	2.74	0.0068	0.32	2.18
12.0	5.15	2.50	2.65	0.007	0.34	2.15
11.5	5.10	2.50	2.60	0.0073	0.34	2.15
11.0	5.10	2.60	2.50	0.0075	0.44	2.15
10.5	5.05	2.65	2.40	0.0078	0.59	2.05
10.0	5.05	2.50	2.55	0.0081	0.75	1.74
9.8	5.05	2.50	2.55	0.0082	0.89	1.60
9.6	5.05	2.51	2.54	0.0083	0.99	1.51
9.4	5.05	2.51	2.54	0.0085	1.05	1.45
9.2	5.05	2.52	2.53	0.0086	1.16	1.35
9.0	5.05	2.52	2.53	0.0088	1.30	1.21
8.8	5.06	2.53	2.53	0.009	1.42	1.10
8.6	5.06	2.53	2.53	0.0091	1.62	0.90
8.4	5.07	2.54	2.53	0.0093	2.03	0.50
8.2	5.09	2.54	2.55	0.0094	2.18	0.35
8.0	5.10	2.55	2.55	0.0095	2.34	0.20
7.8	5.12	2.55	2.57	0.0097	2.44	0.10
7.6	5.14	2.55	2.59	0.0099	2.49	0.05
7.4	5.16	2.55	2.61	0.0100	2.54	0.0
7.2	5.18	2.55	2.63	0.0102	2.54	
7.0	5.20	2.55	2.65	0.0103	2.54	
6.8	5.20	2.55	2.65	0.0105	2.54	
6.6	5.25	2.56	2.69	0.0109	2.55	
6.4	5.30	2.56	2.74	0.0110	2.55	
6.2	5.40	2.56	2.84	0.0113	2.55	
6.0	5.45	2.56	2.89	0.0116	2.55	
5.8	5.50	2.57	2.93	0.0119	2.56	
5.6	5.55	2.58	2.97	0.0120	2.57	
5.4	5.70	2.59	3.11	0.0123	2.58	
5.2	5.75	2.60	3.15	0.0128	2.59	

Table 12 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-184

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
5.0	5.75	2.60	3.15	0.0130	2.59
4.9	5.8	2.60	3.20	0.0130	2.59
4.8	5.85	2.60	3.25	0.0132	2.59
4.7	5.90	2.60	3.30	0.0135	2.59
4.6	5.95	2.60	3.35	0.0138	2.59
4.5	5.97	2.60	3.37	0.0139	2.59
4.4	6.0	2.60	3.40	0.0140	2.59
4.3	6.05	2.60	3.45	0.0141	2.59
4.2	6.10	2.60	3.50	0.0143	2.59
4.1	6.15	2.60	3.55	0.0145	2.59
4.0	6.20	2.61	3.59	0.0150	2.59
3.9	6.26	2.61	3.65	0.0152	2.59
3.8	6.32	2.61	3.71	0.0158	2.59
3.7	6.38	2.61	3.77	0.0160	2.59
3.6	6.44	2.61	3.83	0.0165	2.59
3.5	6.50	2.61	3.89	0.0169	2.59
3.4	6.56	2.62	3.94	0.0171	2.60
3.3	6.62	2.62	4.00	0.0175	2.60
3.2	6.68	2.62	4.06	0.0179	2.60
3.1	6.74	2.62	4.12	0.0183	2.60
3.0	6.80	2.62	4.18	0.0189	2.60
2.9	6.90	2.62	4.28	0.0192	2.60
2.8	6.95	2.63	4.32	0.0198	2.61
2.7	7.00	2.63	4.37	0.0202	2.61
2.6	7.00	2.64	4.36	0.0209	2.62
2.5	7.00	2.64	4.36	0.0215	2.62
2.4	7.00	2.64	4.36	0.0221	2.62
2.3	7.00	2.64	4.36	0.0230	2.62
2.2	7.00	2.60	4.40	0.0240	2.58
2.1	7.00	2.60	4.40	0.0250	2.58
2.0	7.00	2.51	4.39	0.0260	2.58
1.9	7.00	2.60	4.40	0.0270	2.57
1.8	7.00	2.58	4.42	0.0281	2.55
1.7	7.00	2.55	4.45	0.0292	2.52

Table 12 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-184

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
1.6	7.00	2.52	4.48	0.0304	2.49
1.5	6.98	2.50	4.48	0.0315	2.47
1.4	6.98	2.45	4.53	0.0330	2.42
1.3	7.00	2.40	4.60	0.0345	2.37
1.2	7.00	2.30	4.70	0.0360	2.26
1.1	7.00	2.30	4.70	0.0385	2.26
1.0	6.93	2.18	4.75	0.0420	2.14
0.95	6.95	2.15	4.80	0.0430	2.11
0.90	6.98	2.13	4.85	0.0440	2.09
0.85	6.98	2.08	4.90	0.0450	2.03
0.80	6.99	2.04	4.95	0.0465	1.99
0.75	6.99	1.96	5.03	0.0485	1.91
0.70	7.00	1.89	5.11	0.0500	1.84
0.65	7.11	1.85	5.26	0.0520	1.80
0.60	7.22	1.82	5.40	0.0540	1.77
0.55	7.27	1.75	5.52	0.0560	1.69
0.50	7.32	1.67	5.65	0.0590	1.61
0.45	7.44	1.60	5.84	0.0625	1.54
0.40	7.57	1.52	6.05	0.0670	1.45
0.35	7.70	1.35	6.35	0.0720	1.28
0.30	7.84	1.19	6.65	0.0780	1.11
0.25	8.15	0.97	7.18	0.0850	0.88
0.20	8.46	0.71	7.75	0.0940	0.62
0.15	9.06	0.31	8.75	0.1060	0.20
0.10	10.30	0.12	10.2	0.1200	0.0
0.095	10.3	0.12	10.2	0.1220	
0.080	10.4	0.13	10.3	0.1300	
0.070	10.5	0.13	10.4	0.1320	
0.060	10.5	0.14	10.4	0.1400	
0.050	10.5	0.15	10.4	0.1450	
0.040	10.6	0.15	10.5	0.1540	
0.03	10.8	0.17	10.6	0.1700	
0.02	11.2	0.20	11.0	0.1980	
0.015	11.5	0.23	11.3	0.228	
0.01	11.85	0.28	11.6	0.280	

Table 13
PARTIAL INELASTIC CROSS SECTIONS FOR TUNGSTEN-184

<u>E</u> <u>(MeV)</u>	<u>0.111</u>	<u>0.364</u>	<u>0.69</u>	<u>0.904</u>	<u>1.001</u>	<u>1.006</u>	<u>1.15</u>
1.2	0.94	0.275	0.29	0.325	0.20	0.19	0.10
1.1	1.10	0.28	0.295	0.29	0.15	0.15	0.0
1.0	1.32	0.28	0.29	0.25	0.0	0.0	
0.95	1.44	0.28	0.28	0.11			
0.90	1.54	0.28	0.27	0.0			
0.85	1.56	0.27	0.20				
0.80	1.59	0.25	0.155				
0.75	1.62	0.22	0.07				
0.70	1.65	0.195	0.0				
0.65	1.65	0.15					
0.60	1.65	0.113					
0.55	1.60	0.09					
0.50	1.55	0.065					
0.45	1.50	0.04					
0.40	1.45	0.0					
0.35	1.28						
0.30	1.11						
0.25	0.88						
0.20	0.62						
0.15	0.20						
0.10	0.0						

Table 14

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-184

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
1	0.001	10.05	5.67	15.72
2	0.002	7.11	5.65	12.76
3	0.004	5.02	5.64	10.67
4	0.005	4.49	5.64	10.13
5	0.007	3.80	5.64	9.44
6	0.008	3.55	5.64	9.19
7	0.010	3.18	5.64	8.81
8	0.015	2.59	5.63	8.23
9	0.020	2.25	5.63	7.88
10	0.025	2.00	5.63	7.63
11	0.030	1.83	5.63	7.47
12	0.040	1.59	5.63	7.22
13	0.050	1.42	5.63	7.05
14	0.060	1.30	5.63	6.93
15	0.065	1.25	5.63	6.88
16	0.070	1.20	5.63	6.83
17	0.075	1.16	5.63	6.79
18	0.080	1.12	5.63	6.75
19	0.085	1.09	5.63	6.72
20	0.090	1.06	5.63	6.69
21	0.095	1.03	5.63	6.66
22	0.100	1.00	5.63	6.64
23	0.120	0.92	5.63	6.55
24	0.140	0.85	5.63	6.48
25	0.160	0.79	5.63	6.42
26	0.180	0.75	5.63	6.38
27	0.200	0.71	5.63	6.34
28	0.220	0.68	5.63	6.31
29	0.230	0.66	5.63	6.29
30	0.240	0.65	5.63	6.28
31	0.250	0.63	5.63	6.26
32	0.260	0.62	5.63	6.25
33	0.270	0.61	5.63	6.24
34	0.280	0.60	5.63	6.23
35	0.290	0.59	5.63	6.22
36	0.300	0.58	5.63	6.21
37	0.310	0.57	5.63	6.20
38	0.320	0.56	5.63	6.19
39	0.330	0.55	5.63	6.18

Table 14 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-184

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
40	0.340	0.54	5.63	6.17
41	0.350	0.54	5.63	6.17
42	0.360	0.53	5.63	6.16
43	0.380	0.51	5.63	6.14
44	0.414	0.49	5.63	6.12
45	0.420	0.49	5.63	6.12
46	0.430	0.48	5.63	6.11
47	0.450	0.47	5.63	6.10
48	0.460	0.47	5.63	6.10
49	0.470	0.46	5.63	6.09
50	0.475	0.46	5.63	6.09
51	0.480	0.46	5.63	6.09
52	0.490	0.45	5.63	6.08
53	0.500	0.45	5.63	6.08
54	0.532	0.43	5.63	6.06
55	0.550	0.43	5.63	6.06
56	0.575	0.42	5.63	6.05
57	0.590	0.41	5.63	6.04
58	0.600	0.41	5.63	6.04
59	0.625	0.40	5.63	6.03
60	0.650	0.39	5.63	6.02
61	0.683	0.38	5.63	6.01
62	0.700	0.38	5.63	6.00
63	0.750	0.36	5.63	5.99
64	0.800	0.35	5.63	5.98
65	0.850	0.34	5.63	5.97
66	0.876	0.34	5.63	5.96
67	0.890	0.33	5.63	5.96
68	0.910	0.33	5.63	5.96
69	0.930	0.33	5.63	5.95
70	0.950	0.32	5.63	5.95
71	0.970	0.32	5.63	5.95
72	0.980	0.32	5.63	5.95
73	0.990	0.32	5.63	5.94
74	1.000	0.32	5.63	5.94

Table 14 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-184

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
75	1.025	0.31	5.63	5.94
76	1.050	0.31	5.63	5.93
77	1.060	0.31	5.63	5.93
78	1.070	0.30	5.63	5.93
79	1.080	0.30	5.63	5.93
80	1.090	0.30	5.63	5.93
81	1.110	0.30	5.63	5.93
82	1.125	0.30	5.63	5.92
83	1.130	0.30	5.63	5.92
84	1.150	0.29	5.63	5.92
85	1.200	0.29	5.63	5.91
86	1.250	0.28	5.63	5.91
87	1.300	0.28	5.62	5.90
88	1.350	0.27	5.62	5.90
89	1.440	0.26	5.62	5.89
90	1.500	0.26	5.62	5.88
91	1.600	0.25	5.62	5.87
92	1.700	0.24	5.62	5.86
93	1.780	0.24	5.62	5.86
94	1.860	0.23	5.62	5.85
95	1.900	0.23	5.62	5.85
96	2.000	0.22	5.62	5.84
97	2.100	0.22	5.62	5.84
98	2.200	0.21	5.62	5.83
99	2.290	0.21	5.62	5.83
100	2.330	0.20	5.62	5.83
101	2.380	0.20	5.62	5.82

Table 15
CROSS SECTIONS FOR TUNGSTEN-186

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)	$\sigma_{n,2n}$ (barns)
15.0	5.60	2.47	3.13	0.0085	0.56	1.90
14.5	5.55	2.48	3.07	0.0087	0.52	1.95
14.0	5.40	2.48	2.92	0.0090	0.42	2.05
13.5	5.30	2.49	2.81	0.0092	0.38	2.10
13.0	5.25	2.49	2.76	0.0093	0.33	2.15
12.5	5.25	2.51	2.74	0.0095	0.32	2.18
12.0	5.15	2.50	2.65	0.0098	0.34	2.15
11.5	5.10	2.50	2.60	0.0099	0.34	2.15
11.0	5.10	2.50	2.60	0.0102	0.44	2.05
10.5	5.05	2.50	2.55	0.0104	0.59	1.90
10.0	5.05	2.50	2.55	0.0105	0.75	1.74
9.8	5.05	2.50	2.55	0.0106	0.89	1.60
9.6	5.05	2.51	2.54	0.0107	0.99	1.51
9.4	5.05	2.51	2.54	0.0109	1.05	1.45
9.2	5.05	2.52	2.53	0.0110	1.16	1.35
9.0	5.05	2.52	2.53	0.0111	1.30	1.21
8.8	5.06	2.53	2.53	0.0112	1.42	1.10
8.6	5.06	2.53	2.53	0.0114	1.62	0.90
8.4	5.07	2.54	2.53	0.0117	2.03	0.50
8.2	5.09	2.54	2.55	0.0118	2.18	0.35
8.0	5.10	2.55	2.55	0.0119	2.29	0.25
7.8	5.12	2.55	2.57	0.0120	2.39	0.15
7.6	5.14	2.55	2.59	0.0122	2.44	0.10
7.4	5.16	2.55	2.61	0.0125	2.49	0.05
7.2	5.18	2.55	2.63	0.0127	2.54	0.0
7.0	5.20	2.55	2.65	0.0129	2.54	
6.8	5.20	2.55	2.65	0.0131	2.54	
6.6	5.25	2.56	2.69	0.0135	2.55	
6.4	5.30	2.56	2.74	0.0137	2.55	
6.2	5.40	2.56	2.84	0.0139	2.55	
6.0	5.45	2.56	2.89	0.0141	2.55	
5.8	5.50	2.57	2.93	0.0145	2.56	
5.6	5.55	2.58	2.97	0.0149	2.57	
5.2	5.75	2.60	3.15	0.0152	2.58	

Table 15 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-186

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
5.0	5.75	2.60	3.15	0.0155	2.58
4.9	5.8	2.60	3.20	0.0159	2.58
4.8	5.85	2.60	3.25	0.0160	2.58
4.7	5.90	2.60	3.30	0.0162	2.58
4.6	5.95	2.60	3.35	0.0164	2.58
4.5	5.97	2.60	3.37	0.0169	2.58
4.4	6.0	2.60	3.40	0.0170	2.58
4.3	6.05	2.60	3.45	0.0171	2.58
4.2	6.10	2.60	3.50	0.0173	2.58
4.1	6.15	2.60	3.55	0.0179	2.58
4.0	6.20	2.60	3.60	0.0180	2.58
3.9	6.26	2.60	3.66	0.0182	2.58
3.8	6.32	2.61	3.71	0.0189	2.59
3.7	6.38	2.61	3.77	0.0190	2.59
3.6	6.44	2.61	3.83	0.0195	2.59
3.5	6.50	2.61	3.89	0.0200	2.59
3.4	6.56	2.62	3.94	0.0202	2.60
3.3	6.62	2.62	4.00	0.0205	2.60
3.2	6.68	2.62	4.06	0.0210	2.60
3.1	6.74	2.62	4.12	0.0215	2.60
3.0	6.80	2.62	4.18	0.0220	2.60
2.9	6.90	2.62	4.28	0.0225	2.60
2.8	6.95	2.63	4.32	0.0230	2.61
2.7	7.00	2.63	4.37	0.0239	2.61
2.6	7.00	2.64	4.36	0.0245	2.62
2.5	7.00	2.65	4.35	0.0250	2.62
2.4	7.00	2.64	4.36	0.0260	2.61
2.3	7.00	2.64	4.36	0.0270	2.61
2.2	7.00	2.60	4.40	0.0280	2.57
2.1	7.00	2.55	4.45	0.0290	2.52
2.0	7.00	2.50	4.50	0.0305	2.47
1.9	7.00	2.50	4.50	0.0320	2.47
1.8	7.00	2.42	4.58	0.0335	2.39
1.7	7.00	2.40	4.60	0.0345	2.37
1.6	7.00	2.31	4.69	0.0360	2.27

Table 15 (Cont.)

CROSS SECTIONS FOR TUNGSTEN-186

E (MeV)	σ_t (barns)	σ_{non} (barns)	σ_{el} (barns)	$\sigma_{n,\gamma}$ (barns)	σ_{in} (barns)
1.5	6.95	2.26	4.69	0.0380	2.22
1.4	6.95	2.09	4.86	0.040	2.05
1.3	6.95	2.09	4.86	0.0415	2.05
1.2	6.94	2.07	4.87	0.044	2.03
1.1	6.95	2.06	4.89	0.0465	2.01
1.0	6.95	2.04	4.91	0.0495	1.99
0.95	6.96	2.02	4.94	0.0502	1.97
0.90	6.96	1.98	4.98	0.0520	1.93
0.85	6.96	1.92	5.04	0.0530	1.87
0.80	6.96	1.88	5.08	0.0550	1.82
0.75	6.98	1.82	5.16	0.0565	1.76
0.70	7.01	1.77	5.24	0.0580	1.71
0.65	7.07	1.72	5.35	0.0600	1.66
0.60	7.12	1.67	5.45	0.0620	1.61
0.55	7.17	1.61	5.56	0.0660	1.54
0.50	7.21	1.55	5.66	0.0690	1.48
0.45	7.32	1.41	5.91	0.0730	1.34
0.40	7.43	1.37	6.06	0.0790	1.29
0.35	7.60	1.24	6.36	0.0840	1.16
0.30	7.77	1.10	6.67	0.0910	1.01
0.25	8.09	0.92	7.17	0.1001	0.82
0.20	8.50	0.74	7.76	0.1150	0.62
0.15	9.14	0.50	8.64	0.1290	0.37
0.10	9.50	0.14	9.36	0.1440	0.0
0.095	10.0	0.15	9.85	0.1450	
0.080	10.1	0.15	9.95	0.1500	
0.070	10.2	0.16	10.04	0.1570	
0.060	10.4	0.16	10.2	0.1630	
0.050	10.5	0.17	10.3	0.1720	
0.040	10.6	0.19	10.4	0.1850	
0.03	10.8	0.20	10.6	0.2000	
0.02	11.2	0.23	11.0	0.2300	
0.015	11.5	0.27	11.2	0.2650	
0.01	11.85	0.31	11.5	0.3100	

Table 16

PARTIAL INELASTIC CROSS SECTIONS FOR TUNGSTEN-186

<u>E</u>	<u>0.122</u>	<u>0.40</u>	<u>0.73</u>	<u>0.85</u>	<u>1.04</u>
1.2	1.025	0.24	0.515	0.25	0.03
1.1	1.085	0.23	0.48	0.21	0.02
1.0	1.18	0.21	0.43	0.16	0.01
0.95	1.25	0.20	0.41	0.11	0.0
0.90	1.28	0.18	0.37	0.01	
0.85	1.37	0.17	0.33	0.0	
0.80	1.42	0.14	0.26		
0.75	1.51	0.13	0.12		
0.70	1.60	0.11	0.0		
0.65	1.58	0.08			
0.60	1.56	0.05			
0.55	1.51	0.03			
0.50	1.47	0.02			
0.45	1.38	0.0			
0.40	1.29				
0.35	1.15				
0.30	1.01				
0.25	0.82				
0.20	0.62				
0.15	0.37				
0.10	0.0				

Table 17

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-186

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
1	0.001	222.98	15.57	238.55
2	0.002	157.69	15.24	172.92
3	0.004	111.52	15.07	126.60
4	0.005	99.76	15.04	114.80
5	0.007	84.33	15.00	99.33
6	0.008	78.89	14.99	93.89
7	0.010	70.58	14.98	85.56
8	0.015	57.66	14.96	72.62
9	0.020	49.96	14.95	64.91
10	0.025	44.44	14.95	59.40
11	0.030	40.83	14.95	55.79
12	0.040	35.40	14.96	50.36
13	0.050	31.70	14.97	46.66
14	0.060	28.97	14.97	43.94
15	0.065	27.85	14.98	42.82
16	0.070	26.85	14.98	41.83
17	0.075	25.95	14.99	40.94
18	0.080	25.14	15.00	40.13
19	0.085	25.40	15.00	39.40
20	0.090	23.73	15.00	38.73
21	0.095	23.11	15.00	38.11
22	0.100	22.53	15.01	37.55
23	0.120	20.61	15.03	35.65
24	0.140	19.13	15.05	34.18
25	0.160	17.93	15.07	33.00
26	0.180	16.94	15.10	32.04
27	0.200	16.10	15.12	31.22
28	0.220	15.39	15.14	30.53
29	0.230	15.07	15.15	30.22
30	0.240	14.76	15.16	29.92
31	0.250	14.48	15.17	29.65
32	0.260	14.22	15.18	29.40
33	0.270	13.97	15.19	29.16
34	0.280	13.73	15.20	28.93
35	0.290	13.50	15.21	28.72
36	0.300	13.29	15.22	28.52
37	0.310	13.09	15.24	28.33
38	0.320	12.90	15.25	28.14
39	0.330	12.71	15.26	27.97

Table 17 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-186

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
40	0.340	12.54	15.27	27.81
41	0.350	12.37	15.28	27.65
42	0.360	12.21	15.29	27.50
43	0.380	11.91	15.31	27.23
44	0.414	11.45	15.35	26.81
45	0.420	11.38	15.36	26.74
46	0.430	11.26	15.37	26.63
47	0.450	11.03	15.39	26.42
48	0.460	10.92	15.40	26.33
49	0.470	10.81	15.41	26.23
50	0.475	10.77	15.42	26.19
51	0.480	10.71	15.43	26.14
52	0.490	10.62	15.44	26.05
53	0.500	10.52	15.45	25.97
54	0.532	10.24	15.48	25.72
55	0.550	10.09	15.51	25.59
56	0.575	9.89	15.53	25.43
57	0.590	9.78	15.55	25.33
58	0.600	9.71	15.56	25.27
59	0.625	9.54	15.59	25.13
60	0.650	9.38	15.62	25.00
61	0.683	9.18	15.66	24.84
62	0.700	9.09	15.68	24.77
63	0.750	8.83	15.74	24.57
64	0.800	8.60	15.80	24.40
65	0.850	8.39	15.86	24.25
66	0.876	8.28	15.89	24.18
67	0.890	8.23	15.91	24.14
68	0.9100	8.16	15.93	24.09
69	0.930	8.09	15.96	24.05
70	0.950	8.02	15.98	24.00
71	0.970	7.96	16.00	23.96
72	0.980	7.92	16.02	23.94
73	0.990	7.89	16.03	23.92
74	1.000	7.86	16.04	23.90

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Table 17 (Cont.)

LOW ENERGY CROSS SECTIONS FOR TUNGSTEN-186

Point	E (eV)	σ_a (barns)	σ_s (barns)	σ_t (barns)
75	1.025	7.79	16.07	23.86
76	1.050	7.72	16.10	23.82
77	1.060	7.69	16.12	23.81
78	1.070	7.66	16.13	23.79
79	1.080	7.63	16.14	23.78
80	1.090	7.61	16.15	23.76
81	1.110	7.56	16.18	23.74
82	1.125	7.52	16.20	23.72
83	1.130	7.50	16.20	23.71
84	1.150	7.46	16.23	23.69
85	1.200	7.34	16.29	23.64
86	1.250	7.23	16.36	23.59
87	1.300	7.13	16.42	23.56
88	1.350	7.04	16.49	23.53
89	1.440	6.89	16.61	23.50
90	1.500	6.79	16.69	23.48
91	1.600	6.66	16.82	23.48
92	1.700	6.53	16.96	23.50
93	1.780	6.44	17.07	23.52
94	1.860	6.36	17.19	23.55
95	1.900	6.33	17.25	23.57
96	2.000	6.24	17.39	23.63
97	2.100	6.16	17.54	23.70
98	2.200	6.09	17.69	23.79
99	2.290	6.04	17.83	23.87
100	2.330	6.01	17.89	23.91
101	2.380	5.99	17.97	23.96

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NASA CR-54261

(GA-5885)

NEUTRON CROSS SECTIONS FOR TUNGSTEN ISOTOPES

by

G. D. Joanou and C. A. Stevens

November 13, 1964

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